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CONTROL TECHNOLOGY AND EXPOSURE ASSESSMENT FOR OCCUPATIONAL EXPOSURE TO CRYSTALLINE SILICA: Case 24 – BRICK MANUFACTURING

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INTRODUCTION

The National Institute for Occupational Safety and Health (NIOSH), working under an inter-agency agreement with the Office of Regulatory Analysis of the Occupational Safety and Health Administration (OSHA), is conducting a study to survey occupational exposures to crystalline silica and to document engineering controls and work practices affecting those exposures. The performance of a thorough industrial hygiene survey for a variety of individual employers provides valuable and useful information to the public and employers in the industries included in the work. NIOSH will be conducting approximately 30 case study assessments to document engineering controls and the associated worker exposures to crystalline silica. The principal objectives of this survey are:

1. To identify and describe the control technology and work practices in use in operations associated with occupational exposures to crystalline silica, as well as determining additional controls, work practices, substitute materials, or technology that can further reduce occupational silica exposures.

2. To measure full-shift, personal breathing zone, respirable particulate exposures to crystalline silica. These samples provide examples of exposures to crystalline silica among workers across the many industries where silica is encountered. These exposure data, along with the control data described above, provide a picture of the conditions in the selected industries.

One of the industries selected for surveying was the manufacturing of bricks, (SIC code 3251).

The field studies for this project are directed by NIOSH research personnel and are conducted by Battelle Centers of Public Health Research and Evaluation and their subcontractor, Prezant Associates.

Silica is widespread in industry in the United States. Silica exposures have been identified in at least 47 different four-digit SIC codes. These SIC codes contain more than 230,000 establishments employing more than 3.5 million workers. The current OSHA Permissible Exposure Limit (PEL) for respirable dust containing quartz is calculated from the following formula:

$$PEL = \frac{10}{\%\ silica\ +\ 2} \tag{1}$$

The current NIOSH Recommended Exposure Limit (REL) for quartz is 0.05 mg/m^3, while the current American Conference of Governmental Industrial Hygienists (ACGIH®) Threshold Limit Value (TLV®) is 0.1 mg/m^3. A review of OSHA's Integrated Management Information System (IMIS) database shows that many workers are exposed to crystalline silica at concentrations exceeding the OSHA PEL, the NIOSH REL, and the ACGIH TLV. There is a need to understand the nature of these silica exposures, what is causing the exposures, and what steps are being taken or could be taken to reduce the exposures (e.g., engineering controls, work practices, and personal protective equipment).

METHODS

This field study was conducted in accordance with 42 CFR 85a, the NIOSH regulations governing the investigation of places of employment. The first day at the site was spent meeting with company personnel (company management, employees) to arrange sampling on the subsequent day, and to walk through the plant to begin the industrial hygiene assessment of exposure and control technology. Employees with the highest potential silica exposures in each process area or operation were the major focus of the site visit. Workers selected for sampling were briefed on the sampling procedures to be conducted. Because the goal of this study is to assess the effects of engineering controls and work practices on crystalline silica exposures, samplers were placed outside of any respiratory protective equipment worn by the worker. Two days of sampling were conducted at this site, allowing up to two samples per worker to be collected.

Personal respirable particulate samples, approximately eight hours in duration (minimum sample duration of seven hours), were collected for each silica process worker. Respirable particulate samples were collected at a flow rate of 1.7 liters/minutes using a 10-mm nylon cyclone (a Dorr-Oliver cyclone) and a pre-weighed, 37-mm diameter, 5-µm pore-size polyvinyl chloride filter supported by a stainless steel filter support in a two-piece filter cassette sealed with tape or a cellulose shrink band, in accordance with NIOSH Method 7500. In addition to the personal samples, a bulk sample of settled dust was collected in accordance with NIOSH Method 7500. All samples were analyzed by the OSHA Salt Lake Technical Center laboratory.

Sample data sheets were filled out by the field survey team to document all of the samples collected. Information contained on the sample sheets included: facility name, facility location, process name, worker identifier (included only to allow the "matching" of samples from the same worker on different days), job title and task performed, years of experience, pump number, pump flow rate, start times, stop times, and filter number. In addition, any unusual conditions, work practices, and use of personal protective equipment were also noted on the sampling sheets.

During the site visit, information pertinent to process operation and control effectiveness (e.g., control methods, ventilation rates, work practices, use of personal protective equipment, etc.) was also collected. A thorough description of the process is essential to understanding the role of engineering controls and work practices. The work practices and use of personal protective equipment were also recorded for each worker sampled. Information was obtained from conversations with workers to determine if the sampling day was a typical work day. This information helped place the sampling results in proper perspective. Plant and process layout diagrams were also obtained.

The summary of engineering control information includes such items as ventilation flow rates and distance measurements. The proximity of the control systems to open doors or windows, general ventilation intakes and exhausts, and other interacting equipment (i.e., pedestal fans) were also noted. The age and history of the control systems, cost of control installation, maintenance practices, and operation and maintenance costs were determined from facility management, when possible. Any silica sampling data collected by the company showing the effectiveness of the controls were also collected and evaluated (for example, sampling data from before and after the control was installed).

Pertinent data on the employer and the industry were also collected. This information included the number of employees by job title, products produced, processes used, and work schedules. Information gathered about the facility or building(s) included the type of building construction, descriptions of general ventilation present, and age of the facility. This information is helpful for understanding the operations and processes being sampled.

NIOSH researchers calculated the exposures from the analytical results. For each employee sampled, an eight-hour time weighted average (TWA) exposure to respirable dust and respirable crystalline silica was calculated. The TWA was calculated assuming that exposure remained constant during the unsampled period.

Because the samples were single, full-shift samples, when the analysis of a sample results in a value less than the limit of detection (LOD) of the analytical method, the LOD was used to calculate the TWA, and the value(s) are reported as "at or below" the calculated value for individual samples (e.g., $\leq$0.05 mg/m^3). Only descriptive statistics for this site were generated. These included measures of central tendency, such as the mean, median, standard deviation, and the range. For the samples that were below the LOD, LOD derived concentrations were also used to calculate the descriptive statistics.

FACILITY AND PROCESS DESCRIPTION

On June 15-16, 1999 an industrial hygienist from Battelle Centers for Public Health Research and Evaluation (Battelle) and two technicians from Prezant Associates (Prezant) conducted a site visit at a brick manufacturing company (hereafter referred to as Facility 24).

Facility 24 's business is the manufacture of bricks used for residential construction. Approximately 170,000,000 pounds of brick (more than 40,000,000 pieces) are produced each year. The plant has been in operation for over 100 years with the current ownership for the past 50 years.

The facility occupies approximately 30 developed acres. Facility features include:

- a shale pit
- shale stockpiles
- roadways within facility
- a paved parking lot
- open wall, stand-alone sheds over production equipment, parking, packaging, and kilns areas
- production equipment for the loading hopper and pre-crusher operation
- covered conveyors to move materials between production buildings
- a hammer-mill
- a building with the manufacturing equipment for forming bricks
- a building with dryers
- stand alone "beehive kilns"
- a packaging platform
- brick buildings with offices and a lunchroom
- buildings for the storage, packaging, and maintenance activities
- a storage yard for the packaged brick prior to shipping

Facility personnel work 40-44 hours over a 6-day week. Approximately 54 employees at the plant work in areas with some potential for silica exposure. Forty-eight are plant production workers while the remaining six are plant supervisory and maintenance personnel.

The brick production plant facility structure is constructed on a steel frame, with metal walls, concrete floors and metal peaked roofs with skylights. A dividing wall isolates the screening equipment from the pug mill and brick manufacturing equipment. The five active beehive kilns are manufactured from insulating firebrick and are fired with natural gas.

A front-end loader is used to move shale from the stockpile to the loading hopper of the pre-crusher. The grinding plant equipment includes conveyors and a hammer mill. The production plant includes conveyors, surge bins, screening equipment, a die extruding brick machine, texturing machinery and a cart loading line. The loaded carts travel on tracks to a separate building with 40 dryer tunnels and offloading dock. Forklifts load and unload the kilns from a staging area to the packaging deck. At the packaging deck, racks and strapping equipment are used to prepare the brick for the forklifts to load the product onto company flatbed trucks.

Shale is mined from a pit at the site for a three to four month period, and moved to a stockpile, providing sufficient shale for a year and a half of plant operation. Brickbats (broken bricks) are mixed into the shale for recycling. A front-end loader moves the shale material to a hopper where it is then moved by covered conveyor for processing by a pre-crusher, scalping screen, and hammer-mill. The hammer-mill mechanically reduces the shale and brickbats. The milled shale is then moved by conveyor to a set of screens and surge bin in the plant. After a separation, the oversized shale material is moved by conveyor back to the hammer-mill for re-processing.

The milled shale is mixed with water and Additive A®, a lignosulfide compound, in a pug mill, and the plastic mass is extruded through a rectangular die. The resulting column of clay is trimmed, and then coated with a pigment slurry and sand for the selected finish. The pigment slurry is a mixture of silica sand, and pigment materials (manganese sulfate and other clay types) that may also contain silica. Texture sand is hand loaded from bags into a dry mixer in the screening room side of the brick plant. This material is then moved manually to the brick production line.

Automatic equipment slices the extruded column into individual bricks. Workers, called "offbearers," then lift and position the green (wet) bricks from the moving conveyor into stacked tiers on a kiln cart. The carts are moved on a track from the brick plant into a thermally controlled dryer for 3 to 5 days, in preparation for firing. A forklift (squeeze-lift) moves bricks from the dryer platform into the kilns. A worker, called a "sheet-puller," positions metal plates on the kiln floor to keep the forklift from sinking into the pea-gravel lining the floor of the kiln.

The bricks are fired or "burned" in the beehive kilns at 1900° F for 48 hours, evaporating the free water, dehydrating the mass evenly, and oxidizing and vitrifying the finish. The fired bricks cool in the kiln for 12 hours and are removed to the staging area. Here, the bricks are inspected for color match and uniformity. Forklift equipment moves and positions the bricks onto the packaging platform. The bricks are stacked into bundles and bound by a manually controlled strapping machine.

The Process identification numbers for Facility 24 are as follows:

Area 1 Front-end loader operator
Area 2 Hammer-mill operator
Area 3 Brick production plant
Area 4 Dryer and kilns
Area 5 Packaging platform
Area 6 Brick yard

RESULTS

Air Sampling
Medians, means, ranges and standard deviations are given in Table 1 for the respirable silica concentration measurements and Table 2 for the respirable dust concentration measurements. The individual sampling results are given in Attachment I.

In addition to air sampling, three bulk samples of settled dust were taken to determine the presence of quartz, tridymite, and cristobalite. The bulk analyses showed the sample to contain 30%, 20% and 30% quartz and no tridymite, or cristobalite. The percentage of crystalline silica in personal samples ranged from 8.7% to 25% for those samples with a detectable mass of silica.

Table 1
Facility 24 TWA Respirable Silica Concentration Summary Data by Job Title (mg/m^3).

Job Title	n	Mean	Median	Standard Deviation	Range	Number Non-Detected
Brick Machine Operator	2	0.070	0.070	0.051	0.035-0.106	0
Burner	2	0.020	0.020	0.0091	≤0.013-0.026	1
Cutter Operator	2	0.039	0.039	0.024	0.023-0.056	0
Forklift Operator	8	0.029	0.014	0.023	≤0.014-0.076	5
Grinding Room Operator	2	0.075	0.075	0.024	0.058-0.091	0
Loader Operator	2	0.071	0.071	0.020	0.056-0.085	0
Off Bearer	5	0.037	0.029	0.023	0.021-0.077	0
Shader	2	0.036	0.036	0.012	0.028-0.045	0
Sheet Puller	2	0.053	0.053	0.0091	0.047-0.060	0
Transfer Car Operator	4	0.016	0.016	0.00065	≤0.015-0.016	3
Yard Hand	1	0.020	0.020	0	0.020-0.020	0

Table 2
Facility 24 TWA Respirable Dust Concentration Summary Data by Job Title (mg/m^3).

Job Title	n	Mean	Median	Standard Deviation	Range
Brick Machine Operator	2	0.524	0.524	0.333	0.288-0.760
Burner	2	0.103	0.103	0.00218	0.102-0.105
Cutter Operator	2	0.227	0.227	0.120	0.142-0.312
Forklift Operator	8	0.243	0.162	0.224	0.00137-0.538
Grinding Room Operator	2	0.389	0.389	0.0954	0.321-0.456
Loader Operator	2	0.378	0.378	0.0644	0.332-0.423
Off Bearer	5	0.228	0.200	0.0979	0.139-0.386
Shader	2	0.327	0.327	0.0630	0.282-0.371
Sheet Puller	2	0.359	0.359	0.0945	0.292-0.426
Transfer Car Operator	4	0.132	0.121	0.0743	0.0530-0.231
Truck Loader	1	0.0789	0.0789	0	0.07890.0789-
Yard Hand	1	0.167	0.167	0	0.167-0.167

Control Technology and Associated Costs
The silica source in the production process is primarily the ground shale, which may contain 15% - 20% quartz. This raw material also contains 9-13% water, with more water added in the pug mill so that the extruded brick column is 15% water. The post-screening shale material contained enough moisture that it could be formed into a ball by hand and maintain its integrity.

On the first day of sampling, the typical production rate of 159,000 bricks was achieved. On the second day of sampling, 125,000 bricks were produced. Wind speed on both days of sampling was less than 5 mph.

A corporate safety program with a silica emphasis has been implemented since 1994. Particular emphasis on engineering controls has been in effect for the last year. A written health and safety program has been implemented with emphasis on hazard communication, training, medical surveillance, and respiratory protection has been implemented. The corporate safety program information is provided in both English and Spanish. The respiratory medical surveillance program includes a medical questionnaire, annual physical examination, x-rays, and pulmonary function testing. Respirators (3M filtering face piece respirators, models 8511 and 8271 with exhalation valve) are required for four job categories at the site:

Front-end loader operator at the pre-crusher
Hammer-mill and screens operator
Sheet-pullers at the kilns
Cutter-operator

Plant managers reportedly set aside two days per month to attend to matters related to the reduction of worker exposure to silica aerosol. These activities include a safety and health audit (using a checklist), evaluation of implemented and proposed engineering measures, and evaluation of air sampling data with plant and corporate safety and industrial hygiene professionals. Employees interviewed during the visit demonstrated an awareness of the hazards associated with silica exposure as well as the control of this hazard. A silica theme hardhat sticker is provided to employees only upon an oral review of pertinent information. Posters direct employees on proper respirator usage and signs inform personnel where respirators are required.

A safety incentive program provides individual awards for no lost time accidents; quarterly cash bonuses and an annual promotional award. The plant has a record of several different years where there have been no lost time accidents and a recent run of 5 years. A company-wide paid day off was awarded when it recorded a year with no lost-time accidents.

Air sampling has been conducted using consultant and in-house industrial hygienists. This information was used to evaluate the extent of airborne silica exposure by plant personnel and to set priorities for engineering controls and respiratory protection requirements. A maintenance practice checklist has been implemented keyed towards operation and maintenance activities that would mitigate the generation of silica aerosol from production operations.

Silica exposures were controlled by a number of engineering controls and work practices. The front-end loader operator was isolated from silica sources by a cab enclosure. This cab was air-conditioned, allowing the operator to work with the windows and doors closed. An accumulation of dust was visible on the interior of the cab.

Isolation of the hammer-mill operator in an enclosed booth, permitted him to monitor and control both the hammer-mill (60-feet away) and the screens (40-feet away and above). The hammer-mill, screen surge bins, and pug mill were enclosed processes, minimizing the release of silica-containing aerosols. The post-hammer screens were covered with hinged panels, providing limited enclosure. These screens were located in an unoccupied second-floor room with access limited to authorized personnel. Several windows to the exterior of the building were broken, but little visible aerosol was observed. Holes in the wall between the screens and the occupied brick production line were sealed with expanded foam to minimize movement of silica aerosol into the production area.

Dry-pan size-reduction equipment for the shale and brickbats was replaced by a hammer-mill, and was relocated from the structure shared by the production line, to a freestanding structure apart from the plant building. A dust baffle box was installed enclosing the conveyor belt as it exits the hammer-mill. This 20-foot long box contained 5 free-hanging plastic flaps that reduced the flow of silica-contaminated air from the hammer-mill. A 1.4 gpm water spray nozzle was installed between each flap to prevent aerosol generation. A smaller baffle box of similar design was installed at the entrance of the hammer mill, to provide some resistance to the air drawn into and out of the mill. The hammer-mill, in effect, operates as a fan. Any resistance to air flow entering the mill acts as a control measure to minimize the air flow out of the mill.

A dust control foam system was installed on the conveyor supplying the loading hopper of the pre-crusher. This system consists of a drum of citrus-based surfactant, a control panel, hoses, a manifold, and 4 spray heads. This system worked by blanketing the surface of the conveyed material with foam, preventing the generation of silica containing aerosols. The system is not used when it is raining. A fogger-mister had been installed on the hopper of the pre-crusher. However, with the installation of the foam system, the use of the fogger-mister has been reduced.

Another source of silica exposure was from the forklift traffic moving brick into and out of the kilns. Originally, the floors of the kilns were covered with a layer of brick chips and dust. Recently, the floors of several of the kilns were replaced with a layer of washed limestone pea gravel, in an effort to reduce the generation of silica aerosols. When the forklift trucks operated within the kilns, they were driven on a series of 4-foot by 6-foot aluminum plates. These plates were manually set in place by the workers, providing thermal protection and improved traction for the forklift tires. A secondary benefit was reduced dust generation from the forklift traffic. However, moving these plates may have been associated with increased silica exposures due to the required lifting and moving tasks. These activities on the brick-chip floor may have generated silica aerosols that were not substantially diluted given the enclosed nature of the 42-foot diameter kiln. Despite the use of limestone pea gravel and aluminum plates, the potential for silica exposure remains due to bricks that break during firing.

Water sprays for dust control were installed on the feed belts carrying the screened clay through the production facility to the pug mill and the die-extruder. Full-width belt scrapers were installed to remove clay clinging to the conveyor belts. This clay would otherwise dry out, becoming a source of silica aerosol as the conveyor continued to move. Troughing idlers were used to prevent spillage of the screened clay as it moved overhead from the surge bins to the pug mill and the die-extruder in the brick plant. At the time of the survey, the plant was beginning construction of enclosures above the conveyor transition points. Personal comfort fans were installed near the offbearers to minimize their dependence on cross-building ventilation from open cargo doors. Air entering through these doors passed by the pug mill, a source of silica aerosol.

The texture sand mixer was enclosed by the operator holding a flexible sheet over the mouth of the mixer. A framework and nylon fabric barrier was used to enclose the texture sand application. This barrier minimizes the release of aerosol as the sand is dropped from the hopper.

A regular schedule of after-hours cleanup has reduced the accumulation of production materials in the brick production facility. A walk-behind sweeper and push brooms were used for this purpose and a HEPA filter vacuum system was being considered. A Powerboss sweeper was used to control yard dust during the summer months. A water truck with spraybars was used to wet the brickyard and areas around the packaging platform to control dust. Water was applied to these areas five times each shift.

Forklifts travel at relatively low speeds (2-mph) in the areas between the kilns, surge, and packaging due to the unsecured loads of brick and cross-traffic. Yard traffic is 5 mph, while loaded trucks do not exceed 10 mph until reaching the access road.

In the 6 months prior to this survey, a committed effort to reduce the extent of silica exposure at the company has led to an expenditure of $270,000 for engineering controls. These costs include the following:

Installation of gravel floors in the kilns	$900
Water sprays on feed belts in manufacturing	$1,300
Fogger on the pre-crusher hopper	$100
Enclosure of sand texture hopper	$300
New hammer-mill outside production plant	$241,000
Baffle box for hammer-mill	$1,700
Belt scrapers	$13,600
Walk-behind power sweeper	$6,300

The most expensive item, the hammer-mill, was undertaken as both an efficiency improvement, as well as for its capacity to reduce silica exposure. The equipment for the foam application system was provided at no cost by the company that sells the surfactant liquid to Facility 24 at a cost of $600 a month. While there is uncertainty as to how long the pea gravel floors of the kilns will be effective in controlling dust exposures before becoming overly contaminated with brick chips and dust, it is anticipated that they will be replaced twice a year.

Work Practices

Table 3 gives a summary of the job locations within Facility 24, job titles, and work activities. The percentages given for each work activity are for that particular sampling day.

Table 3
Summary of Job Locations, Job Titles, and Activities

Process Area	Job Title/Description	Activities
3	Brick Machine Operator	Both sampling days – 80% of time spent tending to mixer/extruder, including monitoring the mix to ensure proper consistency. 20% of time spent operating brick cutting machine, which includes changing cutting wires and refilling hopper which spreads sand on the tops of the bricks. Worker wore no respirator.
4	Burner	Both sampling days – 100% of time spent operating the kilns, including checking door seals, lighting the burners, and monitoring the process. Worker wore 3M 8511 filtering face-piece respirator 5% of the time (as needed, determined by the worker).
3	Cutter Operator	Both sampling days – 90% of time spent operating brick cutting machine, which includes changing cutting wires and refilling hopper which spreads sand on the tops of the bricks. 5% of time spent mixing slurry which is applied to the tops of the bricks. 5% of time spent preparing sand mix that is added to the hopper. Worker wore 3M 8511 filtering face-piece respirator 100% of the time.
4	Forklift Operator 1	Sampling day one – 100% of time spent operating Caterpillar 50 diesel powered forklift. Operator moved bricks from transfer car area to the kilns, and from the kilns to the yard or other areas for further processing. Worker wore 3M 8511 filtering face-piece respirator 80% of the time, 100% of the time when in the kilns. Sampling day two – 100% of time spent operating Caterpillar 50 diesel powered forklift. Operator moved bricks from transfer car area to the kilns, and from the kilns to the yard or other areas for further processing. Worker wore 3M 8511 filtering face-piece respirator 70% of the time, 100% of the time when in the kilns.
6	Forklift Operator 2	One sampling day only – 100% of time spent operating Toyota gasoline powered forklift. Operator moved stacks of bricks around the yard (outdoors). Worker wore no respirator.
5	Forklift Operator 3	One sampling day only – 100% of time spent operating Toyota diesel powered forklift. Operator moved stacks of bricks from the jig box to the yard, and loaded trucks (outdoors). Worker wore no respirator.
6	Forklift Operator 4	One sampling day only – 100% of time spent operating Toyota gasoline powered forklift. Operator moved stacks of bricks around the yard (outdoors). Worker wore no respirator.
6	Forklift Operator 5	Both sampling days – 100% of time spent operating Caterpillar 110 diesel powered forklift. Operator moved stacks of bricks around the yard and loaded bricks onto trucks (outdoors). Worker wore no respirator.
6	Forklift Operator 6	One sampling day only – 100% of time spent operating Caterpillar 110 diesel powered forklift. Operator moved stacks of bricks around the yard and loaded bricks onto trucks (outdoors). Worker wore no respirator.
2	Grinding Room Operator	Both sampling days – 60% of time spent overseeing grinding operation controls (indoors). 40% of time spent overseeing grinding operation (outdoors) including shoveling and sweeping of fine material. Worker wore 3M 8511 filtering face-piece respirator 100% of the time.

Table 3 - Continued
Summary of Job Locations, Job Titles, and Activities

Process Area	Job Title/Description	Activities
1	Loader Operator	Both sampling days – 90% of time spent operating Caterpillar 950F front-end loader with a 3.75 cubic yard bucket to move shale from storage piles 150 yards to conveyor. 320 cubic yards of shale were moved in a typical day. Dust control agent used to reduce dust emissions from the conveyor. 10% of time spent working on the conveyor. Worker wore 3M 8511 filtering face-piece respirator when not in the cab of the loader.
3	Off Bearer 1	One sampling day only – 100% of time spent moving bricks from a conveyor to rail cars. Worker wore no respirator.
3	Off Bearer 2	One sampling day only – 100% of time spent moving bricks from a conveyor to rail cars. Worker wore no respirator.
3	Off Bearer 3	One sampling day only – 100% of time spent moving bricks from a conveyor to rail cars. Worker wore no respirator.
3	Off Bearer 4	One sampling day only – 100% of time spent moving bricks from a conveyor to rail cars. Worker wore no respirator.
3	Off Bearer 5	One sampling day only – 100% of time spent moving bricks from a conveyor to rail cars. Worker wore no respirator.
5	Shader 1	One sampling day only – 100% of time spent stacking bricks from the conveyor to the box jig. The stack of bricks are then banded and moved to the yard by the forklift operators. Worker wore no respirator.
5	Shader 2	One sampling day only – 100% of time spent stacking bricks from the conveyor to the box jig. The stack of bricks are then banded and moved to the yard by the forklift operators. Worker wore no respirator.
4	Sheet Puller 1	One sampling day only – 55% of time spent assisting the transfer car operators in unloading railcars that move bricks from the drying lanes to the kilns. 35% of time spent laying metal sheets over a layer of crushed brick on the floor of the kiln. The crushed brick is smoothed with a broom before the metal sheet is laid. 10% of time spent dry sweeping with a broom. Worker wore 3M 8511 filtering face-piece respirator while laying the metal sheets and sweeping.
4	Sheet Puller 2	One sampling day only – 55% of time spent assisting the transfer car operators in unloading railcars to move bricks from the drying lanes to the kilns. 35% of time spent laying metal sheets over a layer of crushed brick on the floor of the kiln. The crushed brick is smoothed with a broom before the metal sheet is laid. 10% of time spent dry sweeping with a broom. Worker wore 3M 8511 filtering face-piece respirator while laying the metal sheets and sweeping.
4	Transfer Car Operator 1	One sampling day only – 100% of time spent operating transfer cars. This operation includes moving empty rail cars to the manufacturing area and moving full rail cars from the manufacturing area to the ovens and staging areas for the kilns. Worker wore no respirator.
4	Transfer Car Operator 2	One sampling day only – 100% of time spent operating transfer cars. This operation includes moving empty rail cars to the manufacturing area and moving full rail cars from the manufacturing area to the ovens and staging areas for the kilns. Worker wore no respirator.

Table 3 - Continued
Summary of Job Locations, Job Titles, and Activities

Process Area	Job Title/Description	Activities
4	Transfer Car Operator 3	Both sampling days –100% of time spent operating transfer cars. This operation includes moving empty rail cars to the manufacturing area and moving full rail cars from the manufacturing area to the ovens and staging areas for the kilns. Worker wore no respirator.
6	Yard Hand	One sampling day only – 100% of time spent assisting the bricklayers in the construction of a company sign and maker. Worker wore no respirator.

CONCLUSIONS AND RECOMMENDATIONS

The air sampling results indicated that nine of thirty-two personal exposure samples exceeded the NIOSH REL of 0.05 mg/m^3 for crystalline silica, while two samples exceeded the OSHA PEL for respirable dust containing crystalline silica. It should be noted that RELs are recommended standards, whereas PELs are legally enforceable standards. The two personal exposure samples which exceeded the OSHA PEL were a sample collected on June 15 on a grinding room operator (1.0 times the PEL), and a sample collected on a brick machine operator on June 16 (1.2 times the PEL). While the grinding room operator wore a respirator 100% of the time, and was thus protected, the brick machine operator wore no respirator. The nine samples which exceeded the REL included: samples collected on June 15 from a loader operator, grinding room operator, off bearer, sheet puller, and forklift operator; and samples collect on June 16 from a loader operator, grinding room operator, cutter operator, and brick machine operator. The exposures that exceeded the REL of 0.05 mg/m^3 on June 15 ranged from 0.056 mg/m^3 to 0.091 mg/m^3 of respirable crystalline silica. The exposures that exceeded the REL on June 16 ranged from 0.056 mg/m^3 to 0.106 mg/m^3 of respirable crystalline silica. Table 3 notes which of these employees wore respirators.

It is evident that this facility has invested considerable funds, time, and effort into reducing silica exposures. The results of this survey highlight areas where additional efforts may bring about further reductions in exposure. In some cases, task-based exposure monitoring using direct reading instruments, such as a respirable dust monitor, would help to focus those efforts on the remaining exposure sources. For example, the brick machine operators spend part of their day refilling the hopper which spreads sand on the tops of the bricks. Since the brick machine is a wet process, refilling the hopper is the likely source of exposure. Task-based sampling could confirm (or refute) this assumption, as well as suggest modifications in work practices or additional engineering controls that may reduce exposures further. NIOSH has published research in the past dealing with controlling dust from operations such as bag dumping which may be helpful here.

The grinding room operator spends a portion of their time sweeping and shoveling. Replacing the broom and shovel with a vacuum cleaner equipped with a filter selected based upon the particle size of the dust would eliminate this source of exposure.

The loader operator spends 10% of his time working on the conveyor. Additional sampling could confirm whether this activity is the source of his silica exposure, or if it stems from a problem with the loader cab enclosure. Other NIOSH researchers are currently investigating the effectiveness of enclosed cabs on heavy equipment for reducing exposures to dust.

The off bearer spends his day moving unfired bricks from the extruder line to rail cars. The source of his exposure is not apparent, but may stem from cleaning activities or from dust carried back from the dryers on the rail cars.

Attachment I
Individual Sampling Results
Facility 24

Sample Date	Sample Time (HH:MM)	Resp. Conc. (mg/m^3)	Percent Silica	Silica Conc. (mg/m^3)	Job Title
6/15/99	**7:40**	**0.332**	**17**	**0.056**	**Loader Operator**
6/15/99	**7:26**	**0.456**	**20**	**0.091**	**Grinding Room Operator**
6/15/99	6:55	0.251	14	0.035	Off Bearer 1
6/15/99	7:02	0.142	16	0.023	Cutter Operator
6/15/99	**6:47**	**0.386**	**20**	**0.077**	**Off Bearer 4**
6/15/99	6:51	0.163	18	0.029	Off Bearer 5
6/15/99	7:04	0.288	12	0.035	Brick Machine Operator
6/15/99	6:52	0.0530	nd	≤0.015	Transfer Car Operator 1
6/15/99	**6:42**	**0.426**	**14**	**0.060**	**Sheet Puller 2**
6/15/99	6:38	0.133	12	0.016	Transfer Car Operator 3
6/15/99	7:20	0.105	25	0.026	Burner
6/15/99	**7:35**	**0.583**	**13**	**0.076**	**Forklift Operator 1**
6/15/99	7:27	0.307	13	0.040	Forklift Operator 2
6/15/99	7:01	0.282	10	0.028	Shader 1
6/15/99	7:04	0.197	nd	≤0.014	Forklift Operator 4
6/15/99	7:05	0.0789	nd	0.014	Forklift Operator 6
6/15/99	7:07	0.167	12	0.020	Yard Hand
6/15/99	7:12	0.083	nd	≤0.014	Forklift Operator 5
6/16/99	**6:14**	**0.423**	**20**	**0.085**	**Loader Operator**
6/16/99	**6:51**	**0.321**	**18**	**0.058**	**Grinding Room Operator**
6/16/99	**6:19**	**0.312**	**18**	**0.056**	**Cutter Operator**
6/16/99	6:26	0.139	15	0.021	Off Bearer 2
6/16/99	6:22	0.200	11	0.022	Off Bearer 3
6/16/99	6:01	0.292	16	0.047	Sheet Puller 1
6/16/99	**6:17**	**0.760**	**14**	**0.106**	**Brick Machine Operator**
6/16/99	7:20	0.102	nd	≤0.013	Burner
6/16/99	6:04	0.231	nd	≤0.016	Transfer Car Operator 3
6/16/99	6:09	0.110	nd	≤0.015	Transfer Car Operator 2
6/16/99	7:10	0.00137	nd	≤0.014**	Forklift Operator 3
6/16/99	6:05	0.569	8.7	0.049	Forklift Operator 1
6/16/99	7:22	0.371	12	0.045	Shader 2
6/16/99	6:48	0.127	nd	≤0.014	Forklift Operator 5

* - Not Detected. [LOD/(respirable dust mass)] x 100% was used for percent silica calculation.
** - Sample mass below LOD for respirable dust analysis. Sample was assumed to be 100% silica.
Samples exceeding the NIOSH REL are shown in bold.